Florida Bay: Signs of Ecosystem Stress

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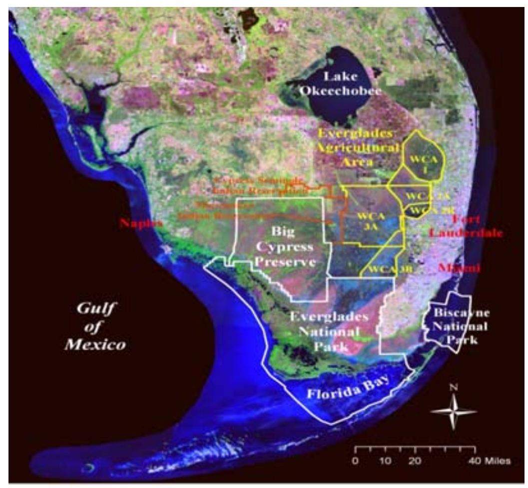
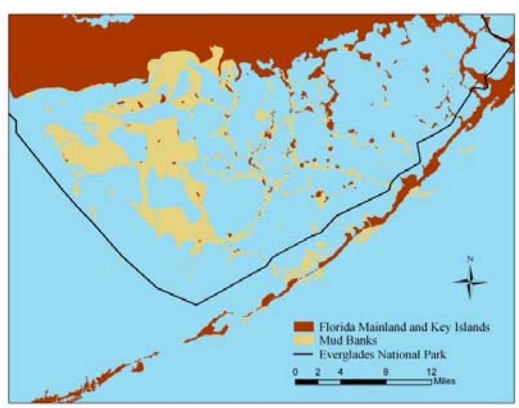
Florida Bay is an ecologically unique, shallow, sub-tropical lagoonal estuary located at the southern end of the Florida peninsula between the Everglades and the Florida Keys. Although historically oligotrophic, significant natural and man-made perturbations in the past several decades have led to persistent algal blooms that now threaten the ecological health of this system. The ongoing restoration of Florida Bay and the Everglades requires the delivery of additional fresh water to these areas to restore hydrologic function and reduce hypersalinity in the estuary. Restoration via management of water deliveries is expected to continue well into the coming decades, and it is important to understand both intended and unintended consequences of re-hydration of the Everglades watershed to the Florida Bay estuary.

Florida Bay has limited exchange with the Gulf of Mexico on its western border, and even more limited exchange with the Atlantic Ocean through tidal passes in the Keys. Thus, internal wind-driven water movement dominates circulation patterns in the bay. High evaporation rates and long residence times often lead to hypersaline conditions. A vast interconnected network of banks and shoals occurs throughout the bay, resulting in numerous quasi-isolated basins where water exchange with neighboring basins is restricted. The geomorphology of Florida Bay has been characterized as similar to an ice-cube tray, with individual sub-basins often having different characteristics than adjacent sub-basins.



Florida Bay and the Everglades-Florida Bay watershed.



Mud banks and key islands create quasi-isolated basins in Florida Bay

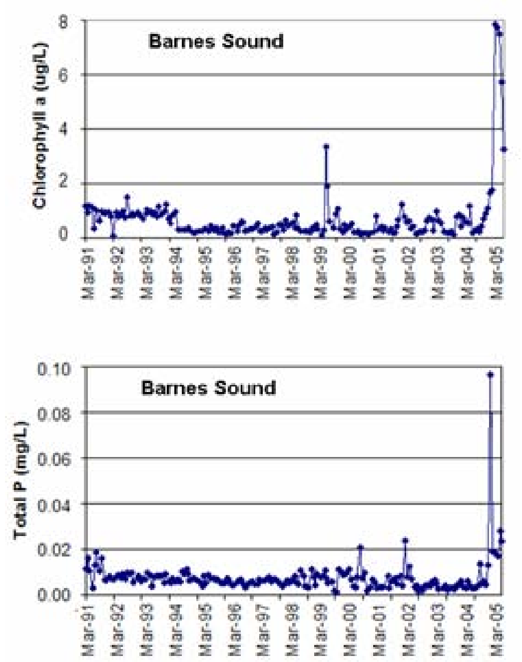
Due to the shallow nature of the bay, seagrasses have historically dominated primary production, providing habitat and supporting productive food webs, and influencing water quality via the stabilization of sediments and uptake of nutrients near the sediment-water interface. Corals and sponges have also been historically common in hard-bottom portions of the bay. However, after decades of benthic dominance with extremely clear water, the bay became very turbid from phytoplankton blooms (*Synechococcus* spp.) in the early 1990s, and while some trends toward increasing water clarity were observed in the late 1990s, extensive phytoplankton blooms began again in 2005. Significant losses of seagrasses have been observed in some areas since this time. These trends have been well characterized by monthly monitoring of the major nutrients and chlorophyll *a* concentrations at 28 bay stations since the early 1990s.

There are numerous major nutrient sources to Florida Bay, including the Gulf of Mexico, the South Florida Peninsula, the Florida Keys, and the atmosphere. Nutrient inputs (particularly nitrogen) from the peninsula include freshwater flow from the Everglades in the eastern bay region, much of which is comprised of overland runoff through small creeks and regulated releases from Canal C-111, which is impacted by the extensively developed southeastern Florida region. The central Florida Bay region receives freshwater flow that traverses the Everglades wetlands and mangroves via the Taylor Slough before reaching the bay. At the western edge of Florida Bay, exchange with the Gulf of Mexico is a major source of phosphorus, with the additional input of some Everglades nutrients via Shark River Slough. In addition, the increasing population and development of the Florida Keys has resulted in increased nutrient inputs from septic sources and stormwater runoff that locally impact waters, including canals, along the southern edge of the bay. Understanding the relationship of the bay's nutrient status and freshwater flow is thus complex, influenced by regulated channelized flow to the east, sheetflow and runoff from the Everglades, rainwater and groundwater, and exchanges with the Gulf of Mexico and Atlantic Ocean. Weather patterns also influence nutrient loading to the bay; nutrient inputs typically increase with the wet season (summer) and decrease significantly with the dry season (winter). The combination of spatially distinct nutrient sources and the dominance of carbonate sediment in the eastern bay have historically led to a system that is phosphorus limited in the eastern region, and more nitrogen limited in the west. Phytoplankton blooms since the 1990s have typically occurred in the central bay where both phosphorus and nitrogen limitation is alleviated.

Recent blooms in Florida Bay have turned the water pea-soup green.

Beginning in September of 2005, an unprecedented phytoplankton bloom appeared in the historically clear waters of the northeastern bay. The dominant species are the same as those prevalent in the central bay blooms: a suite of picocyanobacteria dominated by *Synechococcus* spp. Peak concentrations have exceeded 30 $\mu g\ L^{-1}$, turning the water in some regions a pea-soup green. The initiation of these blooms was coincident with two major system perturbations. First, in 2005 Florida Bay was impacted by a series of hurricanes (Katrina, Rita, Wilma), which resulted in Canal C-111 discharges, and thus large increases in freshwater and nutrient inputs, especially of phosphorus, to Manatee Bay and Barnes Sound. Second, in the same year, construction began on the widening of the 18-mile highway connecting the mainland and the Keys, resulting in the clear-cutting and mulching of acres of mangroves and extensive soil excavation and tilling. The input of organic matter to the eastern bay from this construction is unknown and unquantifiable, but the proximity of the blooms to the region of the construction implicates this as a contributing factor.

Understanding the role of organic nutrients in these blooms has been the focus of NOAA-CSCOR supported research. Indeed, nutrient preferences of *Synechococcus* show that it preferentially responds to organic nutrient forms compared with inorganic forms. While this recent bloom may have been triggered by the events of 2005, as light penetration to the benthos was reduced, increased loss of seagrasses likely led to increased nutrient availability and nutrient release from the sediment. This potentially fueled more phytoplankton production, thus sustaining the blooms. Production has appeared to have shifted from the benthic community to the pelagic community, stabilizing at higher phytoplanktion levels than in previous decades. Simulation models are being developed to better understand both seagrass and plankton nutrient dynamics.



Long-term monthly monitoring of chlorophyll and total P show the dramatic changes that began in 2005.

A change in the state of Florida Bay may thus be occurring, with water column productivity increasing at the expense of benthic productivity. This may be associated with anthropogenically altered nutrient inputs and biogeochemical processes that changed many years ago but which have escalated post-2005. Currently, freshwater flow to Florida Bay is far less than the flow that existed prior to Everglades drainage and water managment, which began in the early 20th century and has provided flood control and water supply to support the dramatically expanded (and still expanding) human population. The long-term ecosystem restoration strategy for the greater Everglades ecosystem, which includes Florida Bay, involves increasing Everglades freshwater flows by the implementation of massive hydrologic restoration projects. Such an increase in flows is a requirement for Florida Bay's restoration, but this could also result in unknown or unintended consequences. It is important that the additional water provided via restoration projects have nutrient concentrations that are low enough to avert estuarine water quality problems, such as sustained algal blooms. Restoration planning and assessment must account for organic nutrient loads as well as inorganic nutrient loads of both nitrogen and phosphorus. As evidenced by the unprecedented persistence of the phytoplankton blooms in eastern bay, which are co-occurring with the blooms in the central bay and now in the southern bay, perturbations, whether natural or man-made, can have wide-ranging and long-term impacts. The bay's sensitive trophic status may be poised between alternate stable states of benthic and pelagic dominance, and appears to be establishing a new set-point around a pelagic-based system at the expense of critical benthic communities. Florida Bay thus appears to be an ecosystem that is sensitive to multiple stressors, that can result in significant changes in the state of the ecosystem.